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INCREASED RIGIDITY SOLUTIONS FOR C-FRAME MECHANICAL PRESSES

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Abstract: *In the framework of sustainable development, reducing energy consumption and increasing energy efficiency are prime targets. Reducing the machine tools' operating power consumption fits into this context. In what presses are concerned, the rigidity increment results in the decrement of the C-frame's elastic deformation and thus the energy consumption is reduced. This paper presents, in summary, some constructive solutions developed by the authors concerning the rigidity increment of casted C-frames, and some results of their behavior obtained by FEA.*

Key words: *C-frame, rigidity, ribs, pre-stressing, sustainable development, FEA.*

1. INTRODUCTION

Crank mechanical presses are machine-tools commonly used in industry.

Energetic consumption of operating presses occurs as a result of frequent elastic deformation of the resistance structure, depending therefore on the stiffness of the machine's frame [5 and 10]. Moreover, the sustainability of the tools and the quality of the processing are significantly influenced by the rigidity of the frame [8].

Given the useful life of mechanical presses, researches to the frame optimization, an essential component repeatedly subjected to considerable stress, are fully justified.

Usually, increased stiffness is obtained as a result of increased consumption of material [7 and 10]. The present paper explores an alternative solution: increasing the stiffness by ribbing the sidewalls of the frame.

Are envisaged, with priority, to increase stiffness and to reduce stress, achieving even higher cost, to ensure total costs – production and exploitation – minimized.

2. STUDY DIRECTIONS

There are a variety of types and constructive solutions for mechanical presses frames. Since the study about the increase of its stiffness cannot be complete, it has been considered the frame of a mechanical crank press PAI 25 as the reference design solution. This press is relatively common in Romania, of good quality and with very good operating results.

In order to increase the stiffness and reduce tensions in the cast C-frame of mechanical presses, three directions have been considered:

- the ribbing of the sidewalls of the frame;
- pretension the frame;
- significantly reducing the distance between th working surface of the table and spindle bore axis.

In a first stage of the research, preliminary, it has been developed a 3D model of PAI 25 press, Fig. 1, which is almost similar to the real model. For this it was used the ProEngineer Wildfire 4 [11] software.

To study the stress and strain state that characterizes the frame of the press PAI 25, there have been provided constraints and external forces, Fig. 2, exactly as in the real case. The stress of the frame is equal with nominal force, F_N = 250 kN.

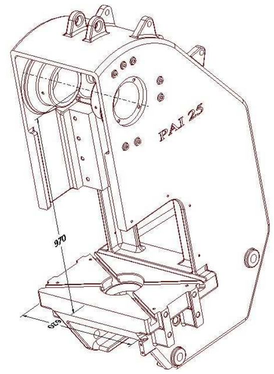

Fig. 1. 3D frame model of the PAI 25 press.

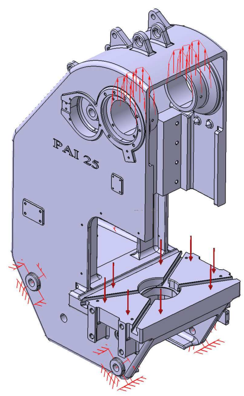

Fig. 2. The application of external forces and constraints on the press frame PAI 25.

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In order to emphasize, virtually, the stress and strain state of the 3D model of the press PAI 25 frame, it was meshed with tetrahedron type elements [6]. It result 37,733 nodes and 19,091 elements. A relevant picture is shown in Fig. 3.

3. CONSTRUCTIVE SOLUTIONS FOR FRAMES WITH RIBBED SIDEWALLS

In all constructive variants, worked on later in the study, there were identically kept the macro geometry of the frame held as reference, constraints and external forces, as well as the meshing manner, for the results of the stress and strain state, in order to be directly compared. Referring only to ribbed frames, which are in fact the subject of this work, they keep intact the entire geometry of the reference frame – to be noted here though that ribs are added to the sidewalls.

3.1. Models' ribbing

Keeping constant sidewalls' thickness of frame, there have been developed models with differently oriented ribs, equidistant in-between at 50, 75 and 100 mm. In a further part of the study, which is not present in this paper, it was taken into account a variation in the thickness of the frame's sidewalls. The geometric characteristics of ribs (g – frame wall thickness, l – distance of ribs arrangement, h – height of ribs, x – thickness of the ribs, $R1$ = 2 mm – peak radius ribs, $R2$ = 5 mm – base radius ribs, ω = 5° – angle of inclination of the side walls of ribs) are suggestively reflected in Fig. 4.

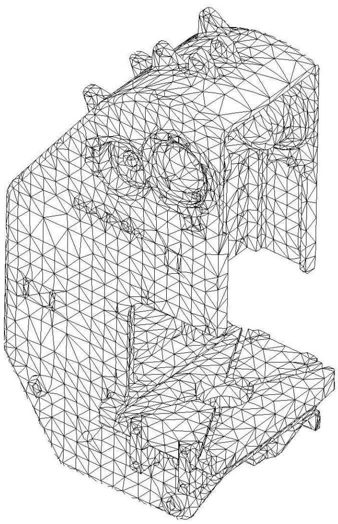

Fig. 3. Discretized model of a PAI 25 press frame.

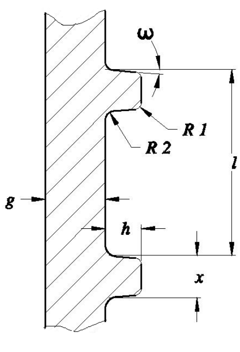

Fig. 4. Geometric characteristics of ribs.

3.2. Frames with horizontal ribs

A ribbed frame first solution considered was a horizontal ribbed one, Fig. 5.

Alternatively, models of frames with horizontal ribs, not equidistant, have been also developed, Fig. 6.

3.3. Frames with vertical ribs

Another group of developed ribbed frames were those with vertical ribs, Fig. 7.

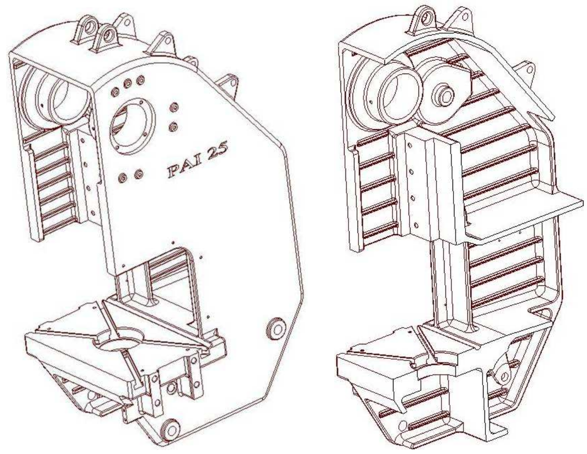

Fig. 5. 3D frame models with horizontal ribs.

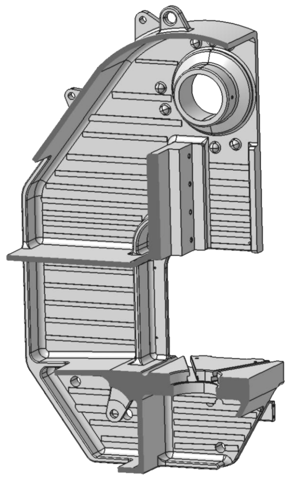

Fig. 6. 3D frame model with horizontal ribs, not equidistant.

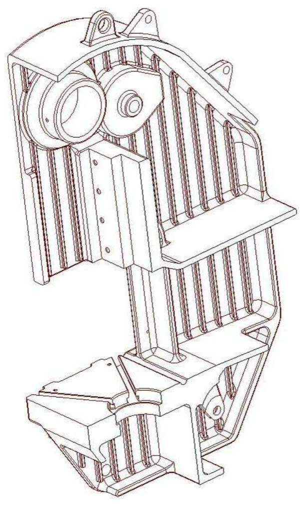

Fig. 7. A 3D frame model with vertical ribs.

3.4. Frames with inclined ribs

They have been developed to study the stress and strain state and it has been taken into consideration the tilted arrangement of the sidewalls ribs, Fig. 8.

The developed models have considered a change from 10 to 10 degrees of the ribs tilt. Models with $\alpha \in$ {10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°} are tilted to the left, meaning towards the front of the frame, and models with $\alpha \in$ {100°, 110°, 120°, 130°, 140°, 150°, 160°, 170°} are tilted to the right, meaning to the rear of the frame.

In Figs. 9 and 10 are shown two frames with tilted ribs, to the left and to the right, respectively.

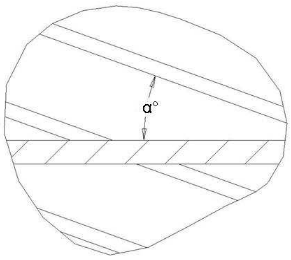

Fig. 8. Inclination angle of ribs.

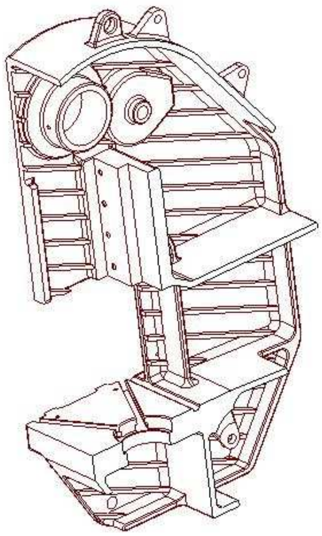

Fig. 9. 3D frame model with left-tilted ribs.

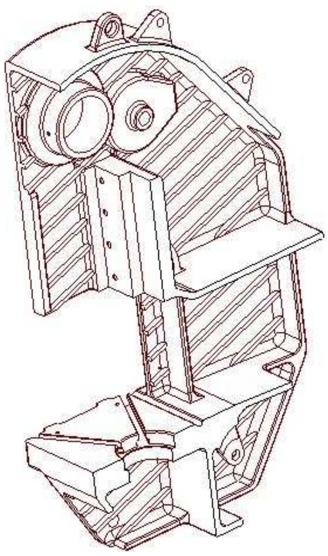

Fig. 10. 3D frame model with right-tilted ribs.

In developing these models it was used parametric design, in order to make easily any change [11].

3.5. Frames with crossing ribs

Applying the combination technique, often used in the invention domain as a method of technical design [1 and 9], different constructive solutions of previously developed frames were combined with each other. The result was a whole family of frames with ribbed sides, and crossing ribs.

Very important for the research were the models with crossing ribs at an angle of 90°, equidistant and horizontally-vertically or tilted-tilted arranged at different angles. Two such models are presented in Figs. 11 and 12.

Several models of frames have been developed, having their walls ribbed with crossing ribs, but not equidistant, Fig. 13.

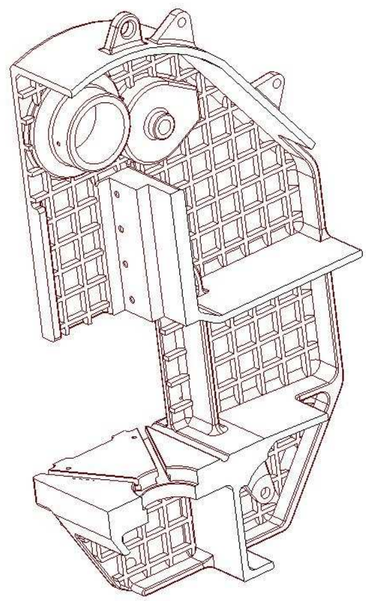

Fig. 11. 3D frame model with crossing ribs, horizontal and vertical, equidistant.

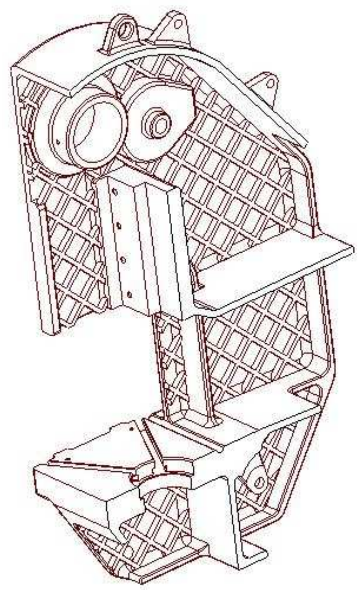

Fig. 12. 3D frame model with crossing tilted ribs, equidistant.

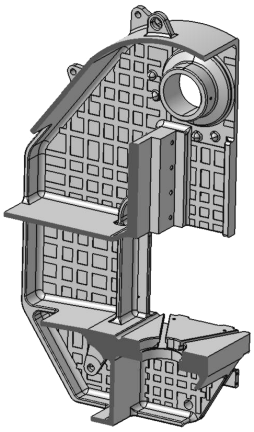

Fig. 13. 3D frame model with crossing ribs, horizontal and vertical, not equidistant.

3.6. Frames with curved ribs

After the study about stress distribution in the frame's body, obvious, perhaps even desirable, became the possibility of ribbing the sidewalls with curved ribs, not equidistant and arranged along the isoclinic lines of the tension state. Such a constructive solution is presented in Fig. 14.

All types of constructive solutions of frames with ribbed walls, developed in order to obtain a frame with increased rigidity, can offer somebody the possibility to apply for a patent.

4. STRESS AND STRAIN STATE IN FRAMES WITH RIBBED SIDEWALLS

At all models of ribbed frames it has been analyzed the strain and stress state using the finite element method [2 and 6].

In all cases, the stress manner and level were kept unchanged, as well as the mesh density of the models, subject which was already noted above.

4.1. Strain state in ribbed frames

The strain state of the studied frames reveals their bending backwards, something known in advance. In Figs. 15, 16 and 17 it is shown the strain state for three constructive solutions.

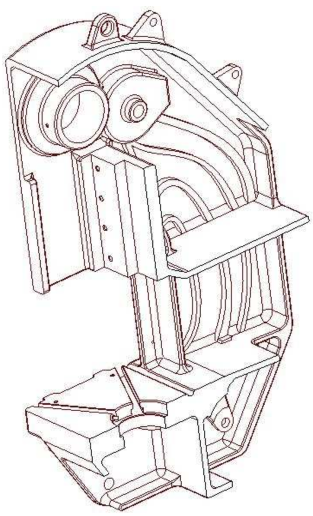

Fig. 14. 3D frame model with curved ribs.

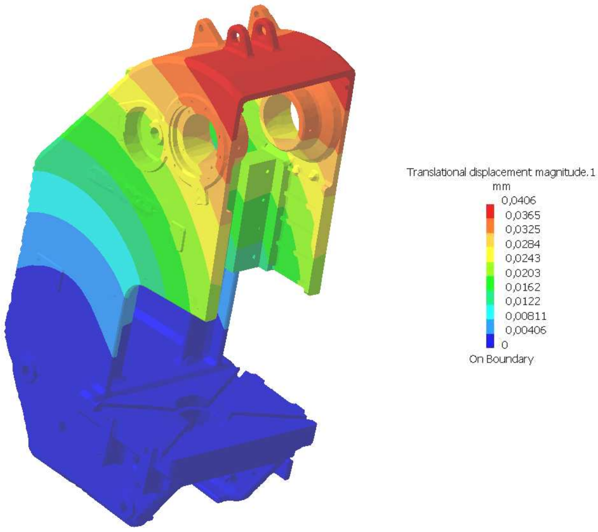

Fig. 15. The strain state in a frame with horizontal ribs.

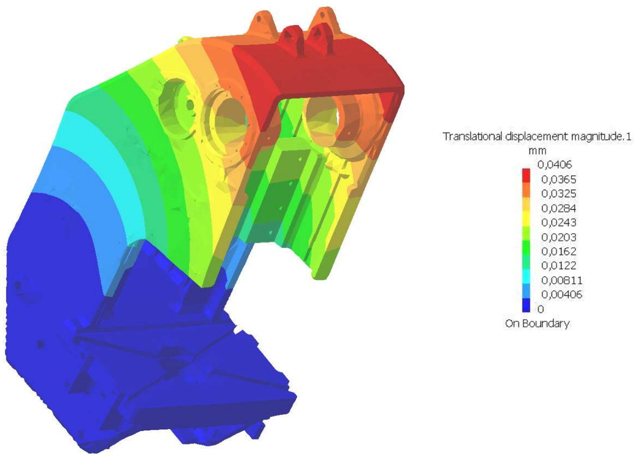

Fig. 16. The strain state in a frame with vertical ribs.

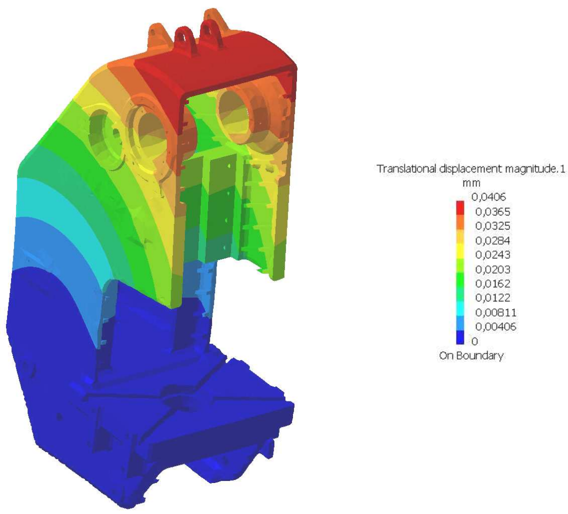

Fig. 17. The strain state in a frame with right-tilted ribs.

It is no interest in whether the frame is deformed in any point of it [3 and 4]. The stored numerical values refer to the displacement in relation to the table plan of the main spindle bore axis. Some results on the deformation of frames with horizontal and vertical ribs, including the taking into consideration of different values for wall thickness, are shown in Fig. 18.

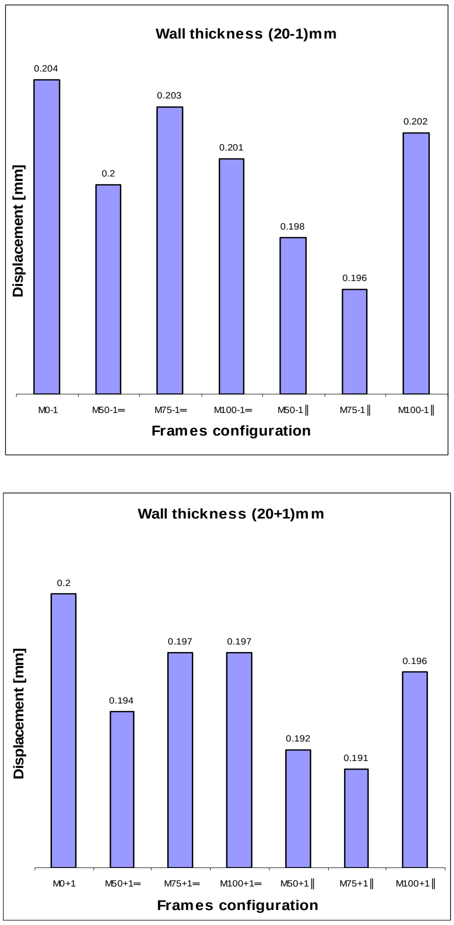

Fig. 18. Deformations of the frame, grouped also according to walls' thickness.

It appears that in all cases the best results are obtained if the ribs are disposed vertically and spaced at 75 mm.

In terms of frames with tilted ribs, two sets of results of main spindle bore axis displacement are shown in Figs. 19 and 20. It is to be seen also the value of the reference model, the one without ribs.

It appears clear that the orientation of the ribs at an angle of 10°, whether to the left or right, leads to the best results in terms of frame rigidity.

4.2. Stress state in ribbed frames

The stress state that manifests in the frames' body does not directly influence their stiffness and aren't therefore a primary objective of the study. However, the study seeks to show that the manifested stress state, preserves, by the new constructive solutions, the stress state corresponding to the reference model, where preferable it is, naturally, to improve it.

Figs. 21 and 22 are presented as examples of stress states occurring in the body of ribbed wall frames, with tilted ribs. Maximum stress values occur, as in the reference model, in the connection areas between the table and front vertical pillars of the frames.

Two sets of maximum values of the tensions that manifest themselves in frames with tilted ribs are shown in Figs. 22 and 23. It appears, as a rule, a slight increase of these values in comparison to the maximum stress value at the reference frame. Additional hardening by ribbing the sidewalls determines, most likely, the migration of the stress state.

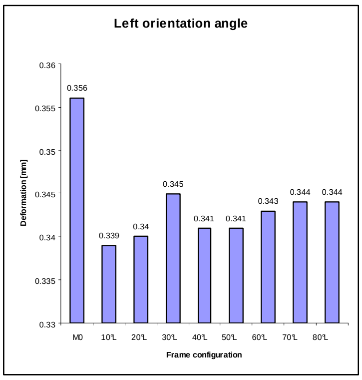

Fig. 19. Deformations of frames with left-tilted ribs.

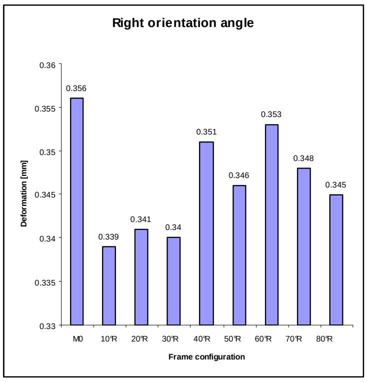

Fig. 20. Deformations of frames with right-tilted ribs.

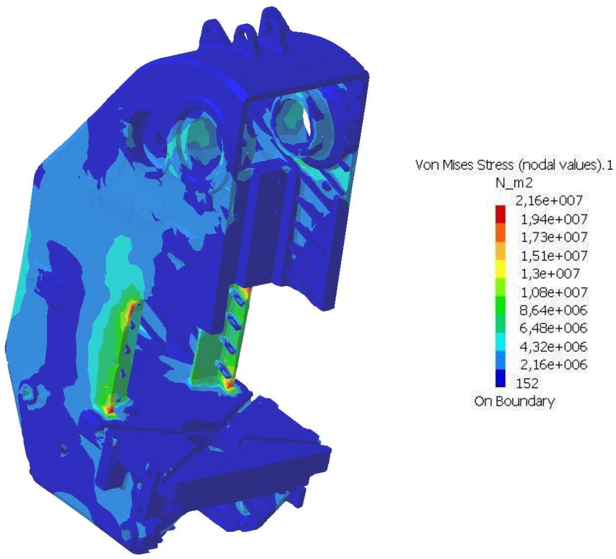

Fig. 21. Stress state at a frame with left-tilted ribs.

5. CONCLUSIONS

Energetic consumption at presses exploitation occurs as a result of frequent elastic deformation of the resistance structure, depending therefore on the stiffness of the machine's frame.

Given the useful life of mechanical presses, researches to the frame optimization, an essential component repeatedly subjected to considerable stress, are fully justified.

Usually, increased stiffness is obtained as a result of increased consumption of material. The present paper explores an alternative solution: increasing the stiffness by ribbing the sidewalls of the frame.

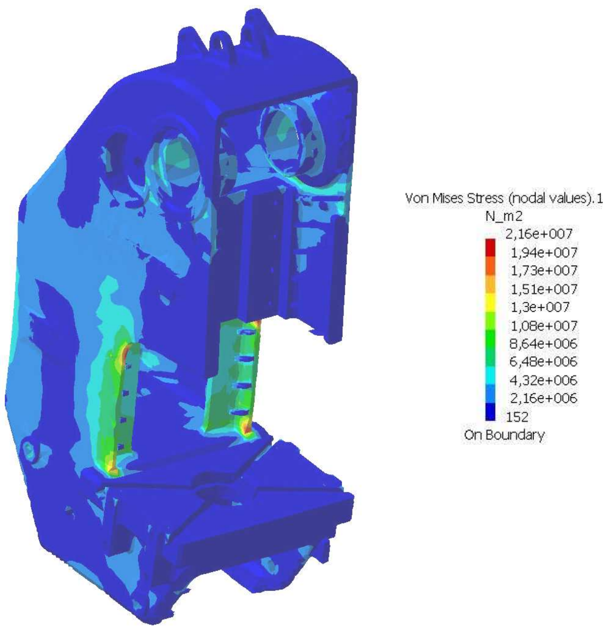

Fig. 22. Stress state at a frame with right-tilted ribs.

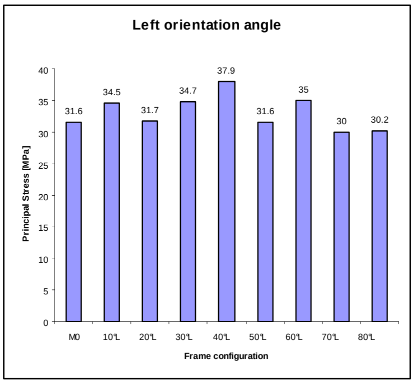

Fig. 22. Maximum stress values in frames with left-tilted ribs.

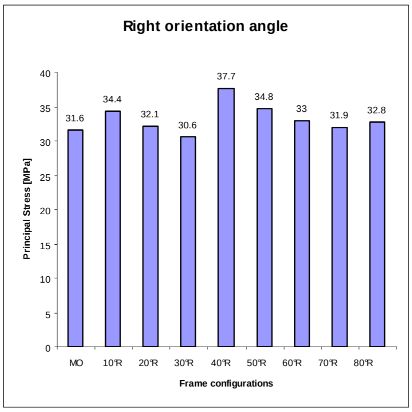

Fig. 23. Maximum stress values in frames with right-tilted ribs.

There are two operating directions to be considered: pretension the frame and significantly reduce the distance between the working surface of the table and main spindle bore axis.

There have been shaped dozens of frame models - with vertical, horizontal, tilted, crossing and curved ribs. Models with changed values of the sidewalls' thickness were developed. All developed models preserve the macro geometry of a reference model.

Finite element analysis is frequently applied to study the strain and stress state of some solids, often of average or high complexity. Press frames fit perfectly into this category.

When studying virtually, it is aimed to identify that constructive solution that provides to the frame the best stress and strain state, including in relation to the reference design solution.

In all versions with ribs there is a lower displacement of the main spindle bore axis to the frame's table, therefore an increase in stiffness.

Solutions with vertical ribs are clearly superior to those with horizontal ones, at least in terms of stiffness. On the other hand, it appears clear that, at the frames with tilted ribs, the arrangement at an angle of 10º, whether to the left or right, leads to the best results.

Analyzing the stress state in the frames with ribbed walls, most often it is found that the increased resistance of ribbed walls causes a 'migration' of tensions to the front pillars areas. Moreover, they are the most in-demand ones at the reference constructive solution also.

REFERENCES

[1] V. Belous, *Inventica* (The Inventics), Edit. "Gh. Asachi", Iași, Romania, 1992.

[2] B. Frederisson et al., *Finite Element Programs in Integrated Software for Structure Mechanics and CAD*. Computer Aided Design, Vol. 13, 1981.

[3] T.T. Haftka et al., *Elements of Structural Optimisation*, 2nd Edition, Kluver, 1990.

[4] C. Ispas et al., *Cercetări teoretice şi experimentale privind deformaţiile elementelor de structură din ansamblul maşinilor-unelte* (Theoretical and Experimental Research Regarding Deformations of Structural Elements of Machine Tools), TCMM, Vol 10, Edit. Tehnică, Bucharest, Romania, 1995.

[5] C. Ispas, C. Mohora, C. Pupăză, M. Zapciu, G. Popoviciu, A. Rusu-Casandra, *Maşini-unelte. Elemente de structură* (Machine Tools. Structural Elements), Edit. Tehnică, Bucharest, Romania, 1997.

[6] Gh. Mogan, *Analiza cu elemente finite în inginerie* (Finit Element Analysis in Engineering), Edit. Universităţii Transilvania Braşov, Romania, 2007.

[7] G. Racz, O. Bologa, *Analiza statică a presei PAI 6 prin metoda elementului finit* (Static Analysis of PAI 6 Press by Finite Element Method), Acta Universitas Cibiniensis, Seria Tehnică, Deformări Plastice, Vol. XLII, 1999, pp. 129–134.

[8] G. Racz, *Contribuţii la optimizarea performanţelor tehnologice ale unor elemente componente ale sistemului tehnologic de prelucrare prin presare la rece* (Contributions to Optimizing Technological Performance of Some Components of the Technological System for Processing by Cold Pressing), PhD Thesis, „Lucian Blaga" University of Sibiu, Romania, 2002.

[9] T.D. Stănciulescu, V. Belous, I. Moraru, *Tratat de creatologie* (Creatology Treaty), Edit. "Performantica", Iași, Romania, 1998.

[10] V. Tabără, I. Tureac, *Maşini pentru prelucrări prin deformare* (Machines for Processing by Plastic Deformation), Edit. Didactică şi Pedagogică, Bucharest, Romania, 1984.

[11] ***, *Fundamentals of Design*, Pro/ENGINEER Wildfire, PTC (Parametric Technology Corporation).